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DePuy

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[54] **CIRCUIT FOR TRIPPING BREAKER**

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[51] **Int. Cl.**[6] **H01H 47/10**

[52] **U.S. Cl.** **361/194**; 361/154; 361/206

[58] **Field of Search** 361/194, 160, 361/170, 154, 152, 102, 115, 206; 335/173, 13

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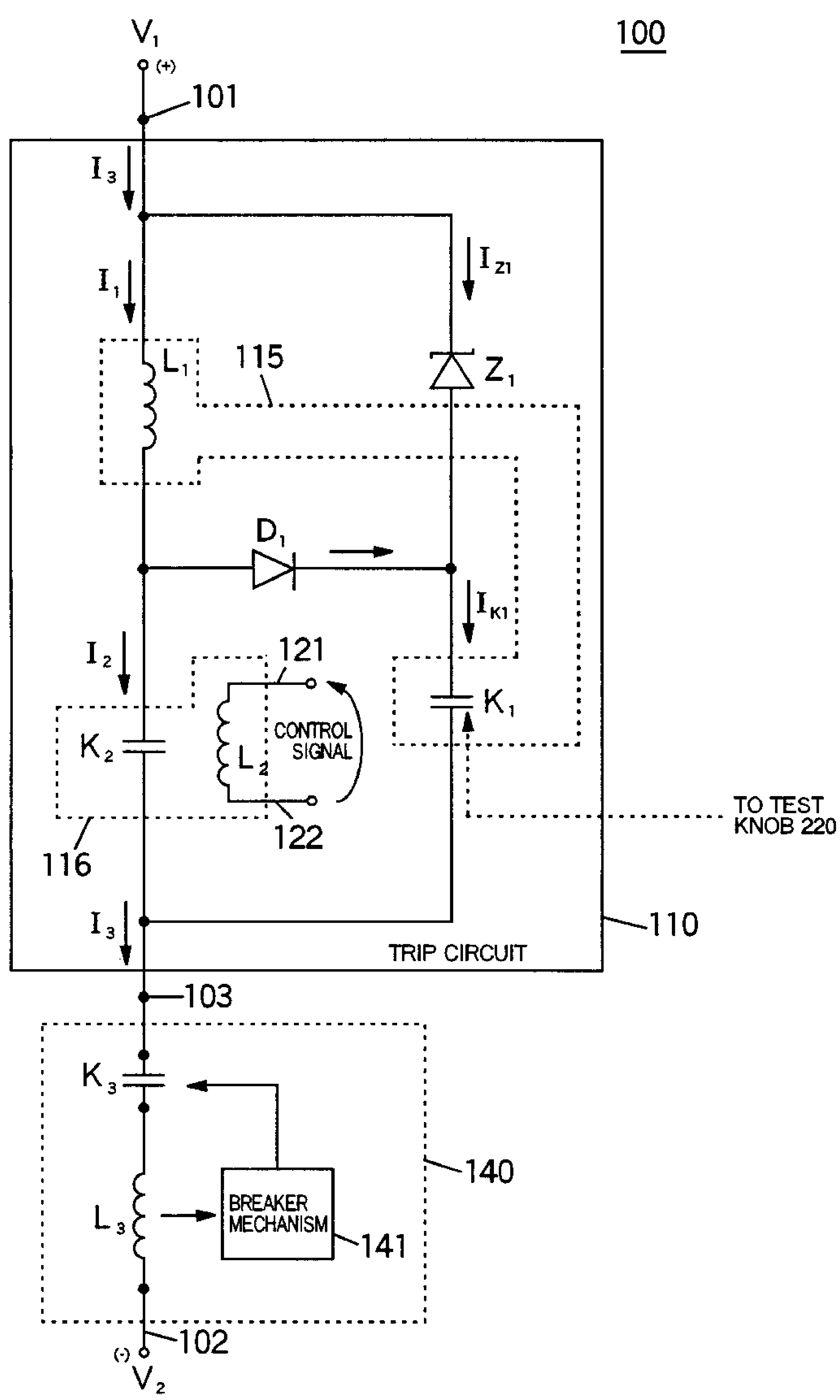
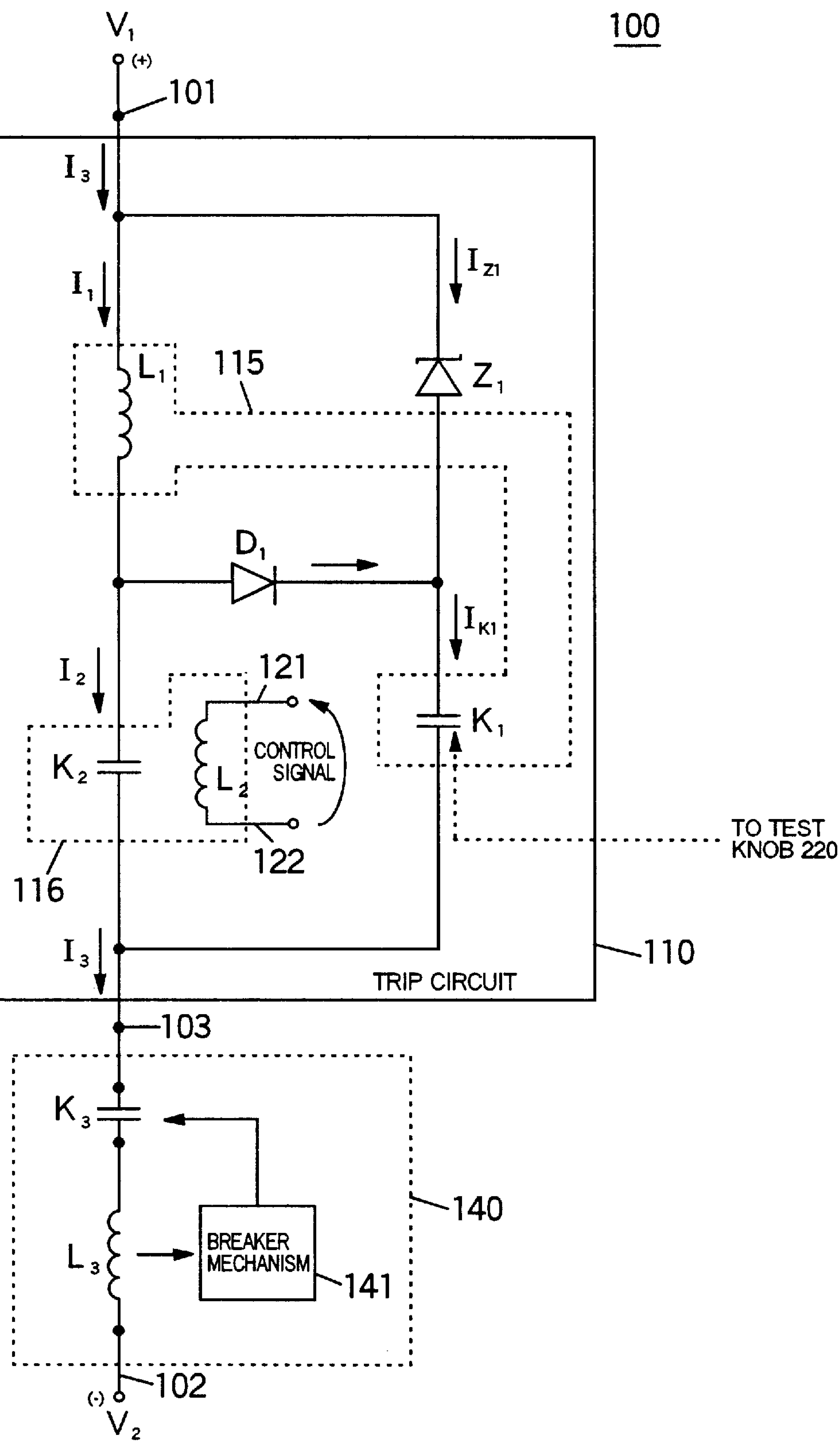
Attorney, Agent, or Firm—Carl B. Horton

[57] **ABSTRACT**

An apparatus for tripping a circuit breaker having a trip coil. A trip circuit is coupled at a first node to a first power supply and at a second node to the trip coil. The trip circuit comprises a switch for closing in response to a control signal, a coil coupled to the switch so that current is allowed to flow through the coil when the switch closes, relay contacts operatively coupled to the coil so that the relay contacts close when current flows through the coil, and a zener diode for providing a low impedance path after the relay contacts close and for applying a holding voltage across the coil sufficient to keep the relay contacts closed while current flows through the low impedance path.

10 Claims, 3 Drawing Sheets





V1
(+)
101
100
I3
I1
IZ1
L1
115
Z1
D1
IK1
I2
121
K2
CONTROL
SIGNAL
L2
K1
122
TO TEST
KNOB 220
116
I3
110
TRIP CIRCUIT
103
K3
140
L3
BREAKER
MECHANISM
141
102
(-)
V2

FIG. 1

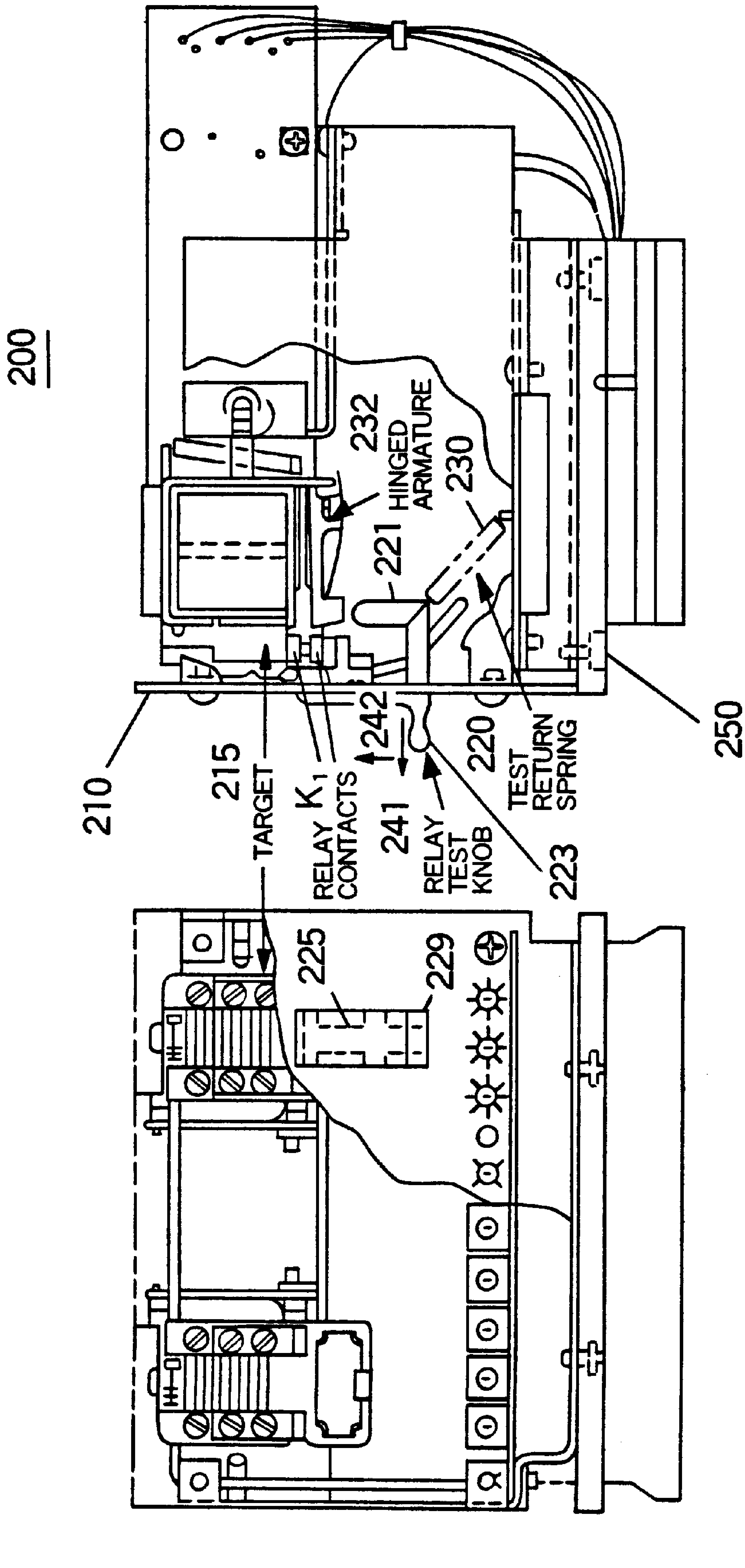

200
232
HINGED
ARMATURE
230
221
210
215
TARGET
RELAY K1
CONTACTS
242
241
RELAY
TEST
KNOB
220
TEST
RETURN
SPRING
223
250
225
229

FIG. 2

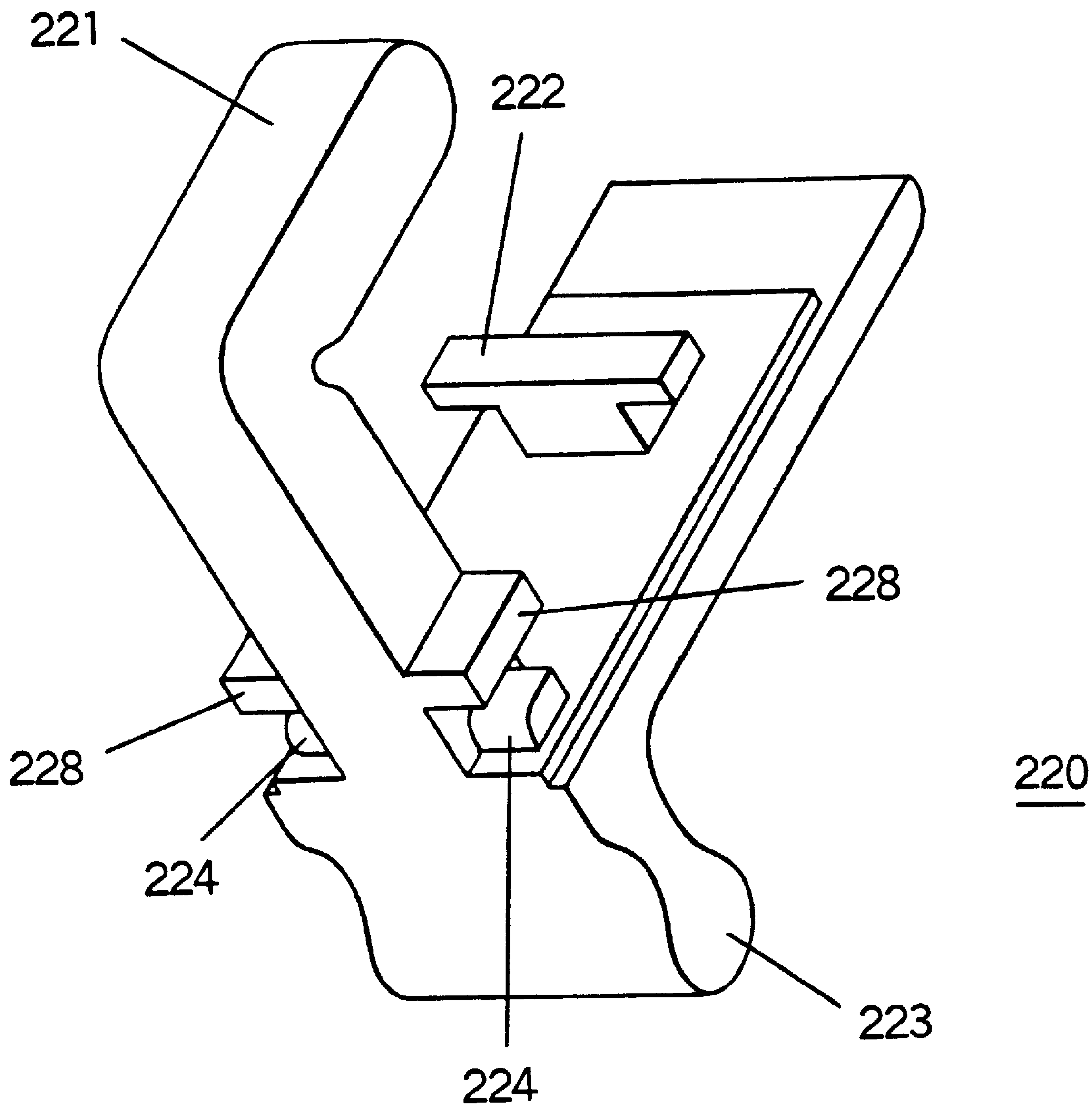


FIG. 3

CIRCUIT FOR TRIPPING BREAKER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to relay circuits and, in particular, to trip circuits for tripping a breaker in response to an overcurrent control signal.

2. Description of the Related Art

Relay circuits are widely used in many applications, such as power systems. Typical uses include protection of utility and industrial feeders and short circuit and overload protection for transformers and motors. Such relays typically include both overcurrent detection circuitry that generates a trip control signal after overcurrent is detected and a trip circuit to energize a breaker trip circuit when the trip control signal is generated. The overcurrent detected may be based on a time or instantaneous overcurrent. Thus, for example, whenever an overcurrent is detected, the overcurrent detection circuitry generates a trip control signal, which is applied to the trip circuit. When the trip circuit receives the trip control signal, the trip circuit causes an appropriate circuit breaker to trip, thus protecting the device or system in which an overcurrent has been detected.

In prior trip circuits, the trip circuit may include a set of relay contacts and a relay coil coupled to the trip control signal. When the trip control signal is applied to the relay coil, the relay contacts are closed, thereby providing a current path for a large current to flow through the closed relay contacts and through a trip coil of the circuit breaker, thereby causing the circuit breaker to trip after the current flows through the circuit breaker trip coil for a sufficient duration of time.

One disadvantage of such trip circuits is that the relay contacts must be large enough to handle the large magnitude of current that is required to flow therethrough in order to trip the circuit breaker. Therefore, the trip control signal must supply a relatively large amount of power to the relay coil in order to close the relay contacts. This power requirement can be undesirable, since the relay system containing the overcurrent detection circuitry and trip circuit often must be self-powered. Additionally, the relay contacts must be held in the closed position by the relay coil until the circuit breaker trips. This increases the power required to trip the breaker, since the trip control signal must be applied to the relay coil until the circuit breaker trips. Further, if the trip control signal is removed from the relay coil for any reason before the circuit breaker trips, the relay contacts may be damaged because they are not normally rated to interrupt the circuit breaker trip coil circuit.

There is a need for improved trip circuits that have lower power requirements and that do not require trip control signals of as long a duration. There is also a need for methods and apparatuses for testing whether such circuits are functioning properly.

SUMMARY OF THE INVENTION

In the present invention, a trip circuit is provided for tripping a circuit breaker having a trip coil. The trip circuit is coupled at a first node to a first power supply and at a second node to the trip coil. The trip circuit has a switch that closes in response to a control signal. A coil is coupled to the switch so that current is allowed to flow through the coil when the switch closes. Relay contacts are operatively coupled to the coil so that the relay contacts close when current flows through the coil. A zener diode is coupled between the first power supply and the relay contacts, and provides a low impedance path between the first power supply and the relay contacts after the relay contacts close. The zener diode also applies a holding voltage across the coil sufficient to keep the relay contacts closed while current flows through the low impedance path and the relay contacts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a circuit containing a trip circuit in accordance with the present invention;

FIG. **2** depicts front and side perspective views of a housing with face plate, target and test knob for housing and testing the trip circuit of FIG. **1**; and

FIG. **3** depicts a perspective view of test knob **220** of the housing of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, there is shown a schematic diagram of a circuit **100** in accordance with the present invention. Circuit **100** includes trip circuit **110**, circuit breaker portion **140**, and terminals (or "nodes") **101**, **102**, and **103**. Terminals **101** and **102** are coupled, respectively, to voltage supplies V_1 and V_2.

Circuit breaker **140** comprises trip coil L_3, breaker mechanism **141**, and auxiliary breaker contacts K_3. Trip coil L_3 is operatively coupled to breaker mechanism **141**, so that when current I_3 has a sufficiently high magnitude, trip coil L_3 trips breaker mechanism **141**, causing breaker mechanism **141** to open one or more breaker main contacts (not shown) in order to protect the device or system in which an overcurrent was detected. When breaker mechanism **141** is tripped, it also opens auxiliary breaker contacts K_3.

Trip circuit **110** comprises relay **115**, which comprises relay coil L_1 and relay contacts K_1. Relay contacts K_1 comprise both upper and lower contacts, which physically contact each other when relay contacts K_1 are closed. The lower contact of relay contacts K_1 is operatively coupled to for manual closure by test knob **220**, as described in further detail below with respect to FIGS. **2** and **3**. Trip circuit **110** also comprises reed switch relay **116**, which comprises reed switch contacts K_2 and reed switch coil L_2. Circuit **110** further comprises zener diode Z_1 and diode D_1. Coil L_2 is coupled to an input control signal at input terminals **121** and **122**. The control signal is received from overcurrent detection circuitry (not shown) that applies a control signal to input terminals **121** and **122** after the overcurrent detection circuitry detects an overcurrent in a monitored device or system (not shown). Coil L_1 of relay **115** is operatively coupled to relay contacts K_1, so that when current I_1 has a sufficiently high magnitude, coil L_1 causes relay contacts K_1 to close. Coil L_2 of relay **116** is operatively coupled to reed switch contacts K_2, so that when the control signal is applied to input terminals **121** and **122**, the current generated through coil L_2 is sufficient to cause reed switch contacts K_2 to close.

As illustrated in FIG. **1**, coil L_1 is coupled at node **101** to the cathode of zener diode Z_1 and at its other terminal to the anode of diode D_1 and to a terminal of reed switch contacts K_2. The cathode of diode D_1 and anode of zener diode Z_1 are coupled through relay contacts K_1 to node **103** and to the other end of reed switch contacts K_2. Node **103** of trip circuit **110** is coupled, through auxiliary breaker contacts K_3 of circuit breaker **140**, to a terminal of trip coil L_3 of circuit breaker **140**. The other terminal of trip coil L_3 is coupled to node **102**.

In one embodiment, zener diode Z_1 has a 5 V breakdown voltage; trip coil L_3 causes auxiliary breaker contacts K_3 to open when current I_3 rises above approximately 5 A; coil L_1 causes relay contacts K_1 to close when current I_1 rises above approximately 0.05 A; and coil L_2 causes reed switch contacts K_2 to close when a control signal of at least 4 V is applied to input terminals **121** and **122**. As explained below, upon receipt of an input control signal, trip circuit **110** provides a low impedance path between nodes **101** and **103**, so that most of the voltage differential (V_1-V_2) is across trip coil L_3. In one embodiment, the voltage differential (V_1-V_2) is 125 V, which is sufficient to generate a voltage across trip coil L_3 of approximately 120 V, which is sufficient to trip breaker mechanism **141**.

In operation, trip circuit **110** is initially an open circuit between nodes **101** and **103**, since reed switch contacts K_2 and relay contacts K_1 are initially open. Auxiliary breaker contacts K_3 are initially closed, since breaker mechanism **141** has not yet tripped. Therefore, initially, voltage differential (V_1-V_2) is applied across nodes **101** and **103**, with no current I_3 flowing through trip coil L_3. When an overcurrent is detected in the system which circuit breaker **140** is designed to protect, a control signal is received at input terminals **121**, **122**. The control signal applied to coil L_2 causes reed switch contacts K_2 to close. At this point, relay contacts K_1 are open and zener diode Z_1 conducts no current I_{Z1}, and the voltage differential (V_1-V_2) causes current $I_3=I_1=I_2$ to flow, at an initial magnitude. Since relay contacts K_1 are open, no current I_{Z1} can flow through zener diode Z_1, since diode D_1 will not allow the current I_{Z1} to pass from the cathode-to-anode of diode D_1. Thus, the voltage across coil L_1 is higher than the voltage across zener diode Z_1, causing the current of coil L_1 to rise more quickly and to close relay contacts K_1 more quickly than if there was a current I_{Z1} flowing through zener diode Z_1. In one embodiment, the impedance of relay coil L_1 is selected so that the impedance ratio of relay coil L_1 to trip coil L_3 causes the voltage drop across relay coil L_1 to be many times the voltage drop V_{Z1} across zener diode Z_1, until relay contacts K_1 close and causes a holding voltage $(V_{Z1}-V_{D1})$ to be imposed across relay coil L_1, where V_{D1} is the forward voltage drop across diode D_1.

Thus, current I_1 rises quickly in coil L_1 and causes relay contacts K_1 to be closed a short time after reed switch contacts K_2 were closed in response to the control signal. When relay contacts K_1 close, current K_1 flows therethrough, and current I_{Z1} flows through zener diode Z_1 after its breakdown voltage is reached. Thus, zener diode Z_1 limits the voltage on coil L_1 to a holding voltage equal to the breakdown voltage of zener diode Z_1 minus the forward voltage drop across diode D_1. This limits the current I_1 to a maximum magnitude to prevent damage to coil L_1, since any extra current flows through zener diode Z_1. Additionally, at this point, a high-magnitude current path is provided, primarily through zener diode Z_1 and relay contacts K_1, since the breakdown voltage of zener diode Z_1 has been reached.

Thus, a current path through zener diode Z_1 and relay contacts K_1 is provided through trip circuit **110** with a sufficiently low impedance so that I_3 reaches a magnitude large enough to trip breaker mechanism **141**. Other currents of much smaller magnitudes flow through coil L_1 and diode D_1. Once contacts K_1 are closed, trip circuit **110** is said to be sealed in, since relay coil L_1 will maintain relay contacts K_1 in a closed position until breaker mechanism **141** is tripped, even if the control signal is removed and/or reed switch contacts K_2 are opened. As will be appreciated, trip circuit **110** stays sealed in because, zener diode Z_1 still provides a holding voltage across coil L_1, keeping relay contacts K_1 closed, even if reed switch contacts K_2 are opened.

The ability of trip circuit **110** to be sealed in in this manner is advantageous as it allows trip circuit **110** to operate without its own power supply, and does not require the control signal to be applied to reed switch coil L_2 until breaker mechanism **141** is tripped, but only until contacts K_1

are closed. Further, as will be appreciated, the power required to operate relay **116** is much smaller than the power required to operate relay **115**. Thus, the power required of the control signal is much lower than it would be if the control signal were required to operate a relay such as relay **115**.

It may be desired to test trip circuit **110**, for example to test the current path from power supply V_1 at node **101** to node **103**, the integrity of the wiring between node **103** of trip circuit **110** and circuit breaker **140**, and the current path of circuit breaker **140** from node **103** to power supply V_2 at node **102**. One way to test trip circuit **110** would be to apply a control signal to terminals **121** and **122** of reed switch coil L_2. However, this may be undesirable because it would require the tester to have a power supply available, and also because it may be inconvenient to access terminals **121** and **122** or to disconnect the overcurrent protection circuitry from these terminals. Another way to test trip circuit is to short circuit relay contacts K_1, for example by coupling a wire around the contacts. However, this may also be undesirable and dangerous to a human operator since a large voltage may exist across relay contacts K_1. Therefore, a mechanical means for testing trip circuit by mechanically closing relay contacts K_1 are provided herein.

Referring now to FIG. **2**, there are depicted front and side perspective views of a housing **200** with face plate **210**, target **215**, and test knob **220** for housing and testing trip circuit **110** of FIG. **1**. Housing **200** houses trip circuit **110**, including the upper and lower contacts of relay contacts K_1 of relay **115**. The face plate **210** contains an channel **225** in which test knob **220** may be moved up or down. Channel **225** also contains a retention hole **229** in face plate **210**, to provide a secured rest position for test knob **220**, as described below. Target **215** is also mounted on face plate **210** and is operated by relay **115**. Housing **200** also comprises a test return spring **230** for coupling test knob **220** to base **250** of housing **200**, as described in further detail below. Housing **200** further includes hinged armature **232**, which is coupled to the lower contact of relay contacts K_1 so that relay contacts K_1 may be closed by moving test knob **220**, and thus armature **232**, upwards, as described further below. In one embodiment, test knob **220** consists of a non-conducting material, such as plastic, to protect a user from possible electrical shock from test circuit **110** while manipulating test knob **220**.

As will be appreciated, when relay contacts K_1 of relay **115** close, relay contacts K_1 physically move together, as illustrated in FIG. **2**. Target **215** is mounted and operatively coupled to relay contacts K_1 such that, when relay contacts K_1 are closed, the target **215** is set. The target **215** comprises a target indicator which displays a visual indication to indicate whether or not relay contacts K_1 of relay **115** have been closed.

Referring now to FIG. **3**, there is depicted a perspective view of test knob **220**. Test knob **220** comprises knob portion **223**, retention tab **222**, retention flange **228**, a stop or stop **210** tabs **224**, and back portion **221**. Test knob **220** is slidably secured in channel **225** of face plate **210**, so that test knob may slide up or down. Test knob **220** is coupled at its back portion **221** to base **250** of housing **200** via test return spring **230**. The lower contact of relay **115** contacts K_1 is attached to a hinged armature **232** so that if armature **232** is moved upwards from a rest position, relay contacts K_1 close. Test knob **220** is mounted so that its back portion will push armature **232** upward when test knob **220** is moved upward in channel **225** by a user. Stop **224** and spring **230** help to prevent accidental operation of test knob **220** by requiring the test knob to be pulled and lifted in order to perform the test. Retention tab **222** and retention flange **228** mount behind the face plate **210** to keep test knob **220** secured.

Retention tab **222** is also mounted in target **215** to limit the stroke of the test knob **220**.

Initially, test knob **220** is in a rest position, with stop **224** placed in a retention hole **229** in face plate **210**. Thus, in this initial rest position, knob **220** is fixed in its lower position and is unable to slide upwards in track **225**. In order to operate test knob **220** to close relay contacts K_1, a user pulls on knob portion **223** directly away from face plate **210**, as illustrated by arrow **241**, thereby removing stop **224** from the retention hole **229**. Retention tab **222** and retention flange **228** prevent knob **220** from being removed completely from face plate **210** in response to further pulling in the direction of arrow **241**. Test knob **220** is at this point is free to slide up in track **225**, as illustrated by arrow **242**. The user then slides test knob **220** upwards, which causes back portion **221** to move hinged armature **232** upwards, causing contacts K_1 to close and target **215** to be set. If trip circuit **110** is operating properly and properly coupled to voltage supply V_1 and circuit breaker **140**, when contacts K_1 are closed, trip circuit **110** becomes sealed in and breaker mechanism **141** of circuit breaker **140** trips. Thus, if a user moves test knob **220** upwards as described above, and target **215** is set and breaker mechanism **141** trips, the current path integrity for tripping has been tested.

It will be understood that various changes in the details, materials, and arrangements of the parts which have been described and illustrated above in order to explain the nature of this invention may be made by those skilled in the art without departing from the principle and scope of the invention as recited in the following claims.

What is claimed is:

1. An apparatus for tripping a circuit breaker having a trip coil, comprising a trip circuit coupled at a first node to a first power supply and at a second node to the trip coil, the trip circuit comprising:

(a) a switch for closing in response to a control signal;

(b) a coil coupled to the switch so that current is allowed to flow through the coil when the switch closes;

(c) relay contacts operatively coupled to the coil so that the relay contacts close when current flows through the coil; and

(d) a zener diode coupled between the first power supply and the relay contacts for providing a low impedance path between the first power supply and the relay contacts after the relay contacts close and for applying a holding voltage across the coil sufficient to keep the relay contacts closed while current flows through the low impedance path and the relay contacts.

2. The apparatus of claim **1**, further comprising mechanical means for closing the relay contacts.

3. The apparatus of claim **1**, further comprising a housing for housing the trip circuit, the housing comprising:

(1) a face plate;

(2) a test knob mounted in a sliding channel of the face plate, the test knob having a knob portion accessible from the exterior of the face plate and a back portion, wherein the relay contacts comprise first and second relay contacts; and

(3) an armature for mounting the second relay contact, wherein the armature is operatively coupled to the back portion of the test knob so that moving the test knob in the sliding channel causes the relay contacts to close.

4. The apparatus of claim **3**, wherein the face plate further comprises a retention hole in the sliding channel and the test knob comprises a stop tab means for securing the test knob in a rest position in the sliding channel when the stop tab means is inside the retention hole, the housing further comprising a spring coupled between the test knob and the housing to pull the stop tab means into the retention hole.

5. The apparatus of claim **4**, wherein the test knob further comprises retention tab means for securing the test knob to the face plate.

6. The apparatus of claim **1**, wherein the current flowing through the low impedance path is sufficient to cause the trip coil to trip the circuit breaker.

7. The apparatus of claim **1**, wherein the switch is a reed switch and the trip circuit further comprises a reed switch coil coupled to the control signal and operatively coupled to the reed switch so that the reed switch coil causes the reed switch to close in response to the control signal.

8. The apparatus of claim **1**, wherein: the relay contacts comprise first and second relay contacts; the switch is a reed switch coupled at a first terminal to the trip coil and to the first relay contact; the reed switch is coupled at a second terminal to a first terminal of the coil and to the anode of a diode; a second terminal of the coil is coupled to the first power supply and to the cathode of the zener diode; and the anode of the zener diode is coupled to the cathode of the diode and to the second relay contact.

9. An apparatus for tripping a circuit breaker having a trip coil, comprising a trip circuit and a housing for housing the trip circuit, wherein the trip circuit comprises:

(a) a switch for closing in response to a control signal, wherein the trip circuit is coupleable at a first node to a first power supply and at a second node to the trip coil;

(b) a coil coupled to the switch so that current is allowed to flow through the coil when the switch closes;

(c) relay contacts operatively coupled to the coil so that the relay contacts close when current flows through the coil; and

(d) means for providing a low impedance path after the relay contacts close and for applying a holding voltage across the coil sufficient to keep the relay contacts closed while current flows through the low impedance path; and the housing comprises:

(1) a face plate;

(2) a test knob mounted in a sliding channel of the face plate, the test knob having a knob portion accessible from the exterior of the face plate and a back portion, wherein the relay contacts comprise first and second relay contacts; and

(3) an armature for mounting the second relay contact, wherein the armature is operatively coupled to the back portion of the test knob so that moving the test knob in the sliding channel causes the relay contacts to close.

10. A trip circuit for tripping a circuit breaker having a trip coil, the trip circuit comprising:

(a) a switch for closing in response to a control signal, wherein the trip circuit is coupleable at a first node to a first power supply and at a second node to the trip coil;

(b) a coil coupled to the switch so that current is allowed to flow through the coil when the switch closes;

(c) relay contacts operatively coupled to the coil so that the relay contacts close when current flows through the coil; and

(d) means, comprising a zener diode, for providing a low impedance path after the relay contacts close and for applying a holding voltage across the coil sufficient to keep the relay contacts closed while current flows through the low impedance path.

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